(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 844 899 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
30.07.2003 Bulletin 2003/31

(21) Application number: **96928169.0**

(22) Date of filing: **14.08.1996**

(51) Int Cl.[7]: **A61N 1/375**, H01L 23/057, H05K 5/00

(86) International application number:
PCT/US96/13170

(87) International publication number:
WO 97/006853 (27.02.1997 Gazette 1997/10)

(54) HERMETICALLY SEALED ELECTRICAL FEEDTHROUGH FOR USE WITH IMPLANTABLE ELECTRONIC DEVICES

HERMETISCH ABGEDICHTETE ELEKTRISCHE DURCHFÜHRUNG ZUR VERWENDUNG BEI IMPLANTIERBAREN ELEKTRONISCHEN VORRICHTUNGEN

TROU D'INTERCONNEXION ELECTRIQUE, SCELLE HERMETIQUEMENT, PREVU POUR ETRE UTILISE DANS DES DISPOSITIFS ELECTRONIQUES IMPLANTABLES

(84) Designated Contracting States:
DE ES FR GB IT

(30) Priority: **16.08.1995 US 515559**

(43) Date of publication of application:
03.06.1998 Bulletin 1998/23

(73) Proprietor: **ALFRED E. MANN FOUNDATION FOR SCIENTIFIC RESEARCH**
Sylmar, CA 91342 (US)

(72) Inventors:
- **SCHULMAN, Joseph, H.**
  Santa Clarita, CA 91351 (US)
- **CANFIELD, Lyle, Dean**
  Lake Hughes, CA 93532 (US)

(74) Representative:
Gleiss, Alf-Olav, Dr.jur. Dipl.-Ing. et al
Gleiss & Grosse
Leitzstrasse 45
70469 Stuttgart (DE)

(56) References cited:
EP-A- 0 266 210
WO-A-95/34342
US-A- 5 280 413
WO-A-82/01134
FR-A- 2 620 275

EP 0 844 899 B1

Printed by Jouve, 75001 PARIS (FR)

Description

Background of the Invention

[0001] The present invention relates to hermetically sealed feedthroughs that allow electrical connections to be made with electronic circuitry or components which are hermetically sealed in housings or cases suitable for implantation within living tissue. More particularly, the invention relates to a hybrid ceramic extremely thin film hermetic seal that permits very thin hermetically sealed housings to be formed wherein electronic circuitry may me placed and protected, yet still allow electrical contact to be readily established with such electronic circuitry through the use of thin film hermetically sealed feedthroughs.

[0002] Hermetically sealed cases or housings are widely used to protect electronic components that may be susceptible to damage or malfunction from exposure to the surrounding environment. For example, a piezoelectric crystal and certain semiconductor devices need to be protected from the atmosphere, and are thus commonly hermetically sealed in a metal can. The hermetic seal is simply an airtight, durable seal that is long-lasting and physically rugged. Sometimes the interior of an hermetically sealed enclosure is filled with an inert gas such as helium, to further retard the deterioration of the component or components inside. As no seal is perfect, the tightness of the hermetic seal, referred to as the hermeticity, is typically measured or specified in terms of the leakage rate through the seal, expressed in cc/sec. Sometimes, for very low leakage rates, the hermeticity can only be measured by placing a radioactive gas within the enclosure and then using an appropriate radiation detector to "sniff" the seal for radioactive leaks.

[0003] Where the electrical component or components are to be implanted in body tissue, the hermetically sealed case (which must be made from a material that is compatible with body tissue, such as platinum or stainless steel or glass) serves a dual purpose: (1) it protects the electrical component or components from body fluids and tissue, which fluids and tissue could otherwise prevent the components from performing their desired function; and (2) it protects the body tissue and fluids from the electrical component or components, which component or components may be made at least in part from materials that may be damaging to body tissue, and which therefore could pose a significant health risk to the patient wherein they are implanted. It is thus critically important that the hermetic seal of an implanted device be especially long-lasting and physically rugged. For this reason, stringent requirements are imposed on the hermeticity of an implanted device, typically requiring a seal that provides a leakage rate of less than 10^{-8} cc/sec.

[0004] In recent years, the size of implanted medical devices has decreased dramatically. It is now possible, for example, to construct a simple stimulator device in a small hermetically sealed glass tube that can be implanted through the lumen of a needle. See, U.S. Patent Nos. 5,193,539; and 5,193,540. With such a small size comes increased requirements for the tightness of the hermetic seal because there is less empty space inside of the sealed unit to hold the moisture that eventually leaks therethrough. The hermeticity requirements of such small devices may thus be on the order of 10^{-11} or 10^{-12} cc/sec. While the small size is thus advantageous, the stringent hermeticity requirements imposed for such small devices makes them extremely difficult to manufacture, and thus increases the cost of manufacture.

[0005] A significant problem associated with an hermetically sealed package, particularly where the package is implanted in living tissue, is the feedthrough mechanism used to allow electrical conductivity between the circuits sealed in the hermetically sealed package, and the environment surrounding the enclosure. Most implanted medical devices, such as a cardiac pacemaker, neural stimulator, biochemical sensor, and the like, require such a feedthrough in order to establish electrical contact between the appropriate circuitry sealed in the hermetically closed package and an external electrode that must be in contact with the body tissue or fluids outside of the sealed package. In a pacemaker, for example, it is common to provide such a feedthrough by using a feedthrough capacitor. A representative feedthrough capacitor is described in U.S. Patent No. 4,152,540. Alternatively, a hermetic feedthrough is typically used to establish electrical connections between the appropriate electronic components or circuitry sealed in the hermetically closed package and an external control device, or monitoring equipment.

[0006] Heretofore, an hermetic feedthrough for implantable packages has consisted of a ceramic or glass bead that is bonded chemically at its perimeter through brazing or the use of oxides, and/or mechanically bonded through compression, to the walls of the sealed package. A suitable wire or other conductor passes through the center of the bead, which wire or conductor must also be sealed to the bead through chemical bonds and/or mechanical compression. The feedthrough is thus circular, and the wire(s) or conductor(s) mounted within the bead are centered or mounted in a uniform pattern centrally positioned within the bead. Such centering is necessary due to the thermal coefficients required for the different expansion rates that occur when heating is made to either cause the compression seal or to cause the oxide or bronze bonding.

[0007] Other related art relating to methods for forming hermetically sealed cases having electrical feedthroughs and vias include United States Patent No. 4,525,766 issued to Petersen, United States Patent No. 4,861,641 issued to Foster et al., and United States Patent No. 4,882,298 issued to Moeller et al. While these patents teach improvements in the art, such teachings are limited to use with semiconductor substrates and are not easily adaptable for use with microminiature devices

implantable within living tissue.

[0008] As implantable devices have become thinner and thinner, the size of the ceramic or glass beads used for electrical feedthroughs has also become smaller and smaller. This means that the holes through the center of the glass beads have likewise become smaller and smaller, and/or that the distance between the center wire or conductor and the wall of the metal case or package has become smaller and smaller. A small distance between the conductor and the metal wall presents a problem in that an electrical short can easily occur therebetween. To prevent the possibility of such a short, which can occur, e.g, if water or other conductive fluid establishes a bridge between the wire and wall on the outside of the package, it is common to insulate the wire on the outside of the can or package with epoxy or other kinds of plastics or waxes. However, as the overall size of the components decreases, it becomes increasingly difficult to make an effective insulating seal in this manner. Further, although using ceramic packages or cases in place of metal packages or cases eliminates this problem (because the ceramic cases are non-conductive), ceramic cases are by their very nature brittle, and must thus be made thicker than metal walls. Hence, use of ceramic packages reduces the ability to make the case very thin. It is thus evident that what is needed is a way to provide a thin hermetically sealed metal package or case having an electrical feedthrough that eliminates or reduces the possibility of shorting between the feedthrough conductor and the metal wall of the package or case.

[0009] U.S. Patent No. 5,280,413 (Pai) shows a hermetically sealed circuit package for use in an air environment in which a feedthrough is formed by a pair of vias extending through a multilayer circuit board, one of which terminates at a pad outside a sealed region and one of which terminates inside the sealed region. The vias are electrically connected together by circuit paths in the circuit board.

[0010] The materials and fabrication methods used in the Pai patent make the teachings thereof unsuitable for use in an implantable device. For example, the Pai device employs a lid that is bonded to a skirt using a conductive adhesive. Conductive adhesives; however, contain plastics, which, as is known in the field of implantable devices, are not hermetic in a living tissue environment, because plastics "leak" in a living tissue environment. (It is known that only some metals, some ceramics, and some glasses are hermetic in a living tissue environment, and that no known plastics are hermetic in such environment, i.e., that all known plastics leak some unacceptable amount of contaminant in an aqueous saline environment.) The lid and skirt shown in the Pai patent, are made from KOVAR, or some other iron-nickel-cobalt alloy. These alloys corrode in a living tissue environment, leading to a loss of hermeticity and contamination. The skirt is bonded to an anchor using conductive solder, which also corrodes in a living tissue environment. Galvanic corrosion would occur in a living tissue environment at a junction between the alloy and the conductive solder. The anchor and vias employed in the Pai patent are made from copper, which also corrodes in a living tissue environment, and the deposition/plating techniques employed to deposit the copper, are generally not hermetic in a living tissue environment. The polyimide substrate suggested by the Pai patent dissolves in a saline living tissue environment. Thus, the Pai device is unsuitable for implantation in a living tissue.

[0011] European Patent No. 0 266 210 (Kukuoka, et al.) shows a hybrid microdevice approach in which a moisture proof cap is hermetically sealed to a metalized layer. The materials and methods employed by the Kukuoka, et al. patent are also unsuitable for implanatation for much the same reason as the Pai materials and methods are unsuitable for implantation.

Summary of the Invention

[0012] The present invention addresses the above and other needs by providing a thin film hermetically sealed feedthrough. Such feedthrough may be used in a wide variety of applications, but typically is used with a very thin hermetically sealed case or housing suitable for implantation within living tissue, thereby permitting electrical connection between electronic circuits or components sealed within the case and electrical terminals on the outside of the case.

[0013] The hermetically sealed feedthroughs and case of the present invention comprise at least one insulating layer that encapsulates and hermetically seals a metal trace. For example, a conductive trace is deposited on an upper surface of a first insulating substrate or layer. The conductive trace is then covered by depositing another insulating layer over the conductive trace so that the conductive trace is effectively sandwiched between two insulating layers. Advantageously, as the insulation layer is deposited over the metal trace, the metal trace becomes hermetically sealed within the insulating layers. As the deposition of the insulating layer is carried out over the metal trace, at least two openings (or channels) are transversely formed therethrough so as to expose different ends or portions of the conductive trace. Additional conductive material is then placed within each of the openings or channels to form conductive paths or links (hereafter "vias") that make electrical contact with the ends or portions of the conductive trace at the respective locations of the vias. A cover is then hermetically sealed or bonded to one of the insulating layers so as to form an hermetically sealed cavity, with at least one of the vias residing inside of the hermetically sealed cavity, and with at least another one of the vias residing outside of the hermetically sealed cavity. Because the via in the hermetically sealed cavity is in electrical contact by way of the conductive trace with the via on the outside of the hermetically sealed cavity, an electrical feedthrough is thus advantageously provided that

allows electrical contact to be made between the via on the inside of the hermetically sealed cavity and the via on the outside of the hermetically sealed cavity. Hence, electronic circuitry or components may be mounted within the hermetically sealed cavity, and electrical contact can be established with such circuitry or components from a location outside of the hermetically sealed cavity, as required, for a given application.

[0014] In accordance with one aspect of the invention, the insulating layers that hermetically sandwich the metal trace may be deposited on a thin metal substrate, thereby allowing an extremely thin feedthrough to be made.

[0015] In accordance with another aspect of the invention, the insulating layer(s) and/or substrate are made from aluminum oxide Al_2O_3, or other suitable insulating material, such as magnesium oxide, zirconium oxide, or many types of glass, and may be deposited using conventional deposition techniques.

[0016] It is thus a feature of the present invention to provide an hermetically sealed thin film feedthrough.

[0017] It is another feature of the invention to provide such a hermetically sealed thin film feedthrough in combination with a thin hermetically sealed cavity wherein electronic components and/or circuitry may be housed, thereby allowing electrical connections to be established with the circuitry and/or components within the sealed cavity from a location outside of the cavity.

[0018] It is another feature of the invention to provide an extremely thin hermetically sealed housing, including hermetically sealed feedthroughs for allowing electrical contact to be established between the inside and outside of such housing, suited for protecting electronic circuitry and/or components from a hostile environment.

[0019] It is yet an additional feature of the invention to provide an extremely thin hermetically sealed housing, including hermetically sealed feedthroughs that permit electrical connections between the inside and outside of the sealing housing, especially suited for implantation in living body tissue, e.g., especially suited for implantation in animals or humans.

[0020] It is still another feature of the invention to facilitate the manufacture and use of tiny, thin hermetically sealed electrical circuits or components.

Brief Description of the Drawings

[0021] The above and other aspects, features and advantages of the present invention will be more apparent from the following more particular description thereof, presented in conjunction with the following drawings wherein:

FIG. 1 is a side, cross sectional view of the embodiment of the hermetically sealed case and hermetic feedthroughs for implantable electronic devices in accordance with the present invention;

FIG. 2 is a side, cross sectional view of another embodiment of the hermetically sealed case and hermetic feedthroughs for implantable electronic devices in accordance with the present invention;

FIG. 3 is a side, cross sectional view of still another embodiment of the hermetically sealed case and hermetic feedthroughs for implantable electronic devices in accordance with the present invention;

FIG. 4 is an exploded perspective view of yet another embodiment of the present invention illustrating the arrangement of a hermetically sealed case and hermetic feedthroughs for an implantable biochemical sensor comprising a plurality of insulating layers and a plurality of hermetic feedthroughs; and

FIG. 5 is a side, cross sectional view of the embodiment of FIG. 4 illustrating the plurality of insulating layers and a plurality of hermetic feedthroughs.

Detailed Description of the Invention

[0022] The following description includes several embodiments of the hermetically sealed case and hermetic feedthroughs for use with implantable electronic devices and collectively is a description of the best mode presently contemplated for carrying out the invention. This description is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of the invention. The scope of the invention should be determined with reference to the claims.

[0023] As shown in FIG. 1, a first embodiment of the hermetically sealed case 10 for an implantable electronic device includes a substrate 20 (which may or may not be insulating), two insulating layers 22 and 26, one or more hermetic feedthroughs 30, and a cover 40. In this first embodiment, a first insulating layer 26, preferably made from aluminum oxide Al_2O_3 or other suitable insulating material such as magnesium oxide or zirconium oxide, is deposited on a selected substrate 20, using conventional deposition techniques. (It is noted that the substrate 20, if insulating, may serve the function of the first insulating layer 26.) One method of depositing the insulating layer, for example, is to use ion enhanced evaporated sputtering of aluminum oxide. Advantageously, ion enhanced evaporated sputtering of aluminum oxide, or magnesium oxide, or zirconium oxide, forms a high quality insulation layer.

[0024] A metalized pattern or trace of a suitable conductive material 32 is then deposited on the upper surface 27 of the first insulating layer 26, the lower surface 29 of the first insulating layer 26 being adjacent to the substrate 20. (In those instances where the substrate 20 is already an insulator, the metalized trace 32 may be deposited directly on an upper surface of the substrate 20, which substrate then serves the function of the first insulating layer 26.) The metalized trace or pattern may be deposited on the insulating layer 26 using conventional techniques as are well known in the art.

[0025] A second insulating layer 22, having an upper

surface 23 and lower surface 25 is then deposited over the conductive material 32 and the first insulating layer 26 using conventional deposition techniques. The conductive material 32 is thus sandwiched between the lower surface 25 of the second insulating layer 22 and the upper surface 27 of the first insulating layer 26, thereby encapsulating the trace of conductive material 32 within insulating material.

[0026] At least two openings are formed through the second insulating layer 22 to expose the trace of conductive material 32. Such openings may be formed using conventional semiconductor processing techniques. For example, portions of the first insulating layer 26 and/or trace of conductive material 32 may be masked as the second insulating layer 22 is sputtered (or otherwise deposited) onto the first insulating layer 26 and conductive material 32. One of the openings may be formed in the second insulating layer 22 at or near an interior end 33 of the conductive material, while another of the openings may be formed in the second insulating layer 22 proximate an exterior end 34 of the conductive material 32. Such openings are then filled with a suitable conductive metal, such as platinum or tungsten, that forms an interior conductive via 35 and an exterior conductive via 36 at the respective ends 33 and 34 of the conductive trace 32.

[0027] A similar conductive trace 32', with interior conductive via 35' and exterior conductive via 36' near exterior end 34' may similarly be formed on another area of the substrate 20, as needed. Electronic circuitry 45 may then be positioned near the interior portion of the substrate and electrically connected to the interior conductive vias 35, 35' in conventional manner.

[0028] An important feature of the invention is that the deposition processes used to cover or sandwich the metal trace with an insulating layer(s) also hermetically seals the metal trace, i.e., completely encapsulates the metal trace within the insulating material. Further, even at the boundary of the metal trace with the insulating layer(s), an effective hermetic seal is created. The metal trace remains hermetically sealed at all locations except possibly at the point where the openings or holes are made for the vias. That is, some leakage may occur through the via from one layer to the next. (This is because the via may not be, and indeed does not have to be, perfectly plugged with a conductive material that is added after the opening or hole is made. Moreover, even it were completely plugged, there would still likely be some leakage around the edges of the via.) However, such leakage through the via is blocked at the intersection of the via with the next layer. As a result, there is no leakage between, e.g., via 36 and via 35, even though there may be some leakage through via 36 between the upper surface 23 of layer 22 and the lower surface 25 of the layer 22. The lower surface 25 of layer 22 is hermetically sealed to the metal trace 30 and to the upper surface 34 of the next layer 26, so the hermetic seal is preserved.

[0029] A metal cover 40, e.g., formed to have a cross section like that of a top hat, provides a cavity 42 under its center area with flat edges 44 therearound. The flat edges 44 are designed to be tightly bonded to the upper surface of the second insulating layer 22, thereby sealing the cavity 42. The interior conductive vias 35, 35', and electronic circuitry 45, are positioned to reside within of the cavity 42 formed by the metal cover 40, while the other exterior conductive vias 36, 36' reside outside of the metal cover 40, and hence outside of the sealed cavity 42. An electrical path, or "electrical feedthrough" is thus provided between the outside of the sealed cavity 42 and the inside of the sealed cavity 42 through the respective conductive vias 35,36 and the conductive trace 32, and/or the respective conductive vias 35', 36' and the conductive trace 32'. Thus, electrical contact may be made with electronic circuitry 50, or other electrical devices, e.g., sensors or temperature probes, mounted and hermetically sealed within the cavity 42.

[0030] In accordance with one aspect of the invention, the thinness of the hermetically sealed case is facilitated, in the first embodiment, by making the substrate from a thin metal wall. The metal wall may be, e.g., on the order of 50.8 x 10^{-6} to 254 x 10^{-6} m (.002 to .010 inches) thick. For example, if the wall is, e.g., 102 x 10^{-6} m (.004 inches of 4 mils) thick, and assuming that aluminum oxide layers are used that are only on the order of 6.35 x 10^{-6} m (0.25 mils) thick, and also assuming that the metal cover is also about 102 x 10^{-6} (4 mils) thick, it is thus possible to construct an hermetically sealed case that is only about 2.16 x 10^{-6} - 2.29 x 10^{-6} m (8.5-9.0 mils) thick at its edges, and only as thick at its center as is required to form a cavity between the metal walls that houses appropriate electrical components.

[0031] Note that the insulating layers will typically have a thickness less than 25.4 x 10^{-6} m (1 mil), e.g., 6.35 x 10^{-6} m (0.25 mils).

[0032] Referring to FIG. 2, another embodiment of the hermetically sealed case 10 and hermetic feedthroughs 30 for implantable electronic devices is shown. This embodiment is similar to the previously described embodiment, however, the plurality of openings or vias are not confined to pass through only the second insulating layer 22. Much like the prior embodiment, this embodiment includes at least two insulating layers 22 and 26, preferably made from aluminum oxide Al_2O_3, zirconium oxide Zr_2O_3, magnesium oxide Mg_2O_3, or another suitable insulating material. A metalized pattern or trace of a suitable conductive material 32 is deposited on the first insulating layer 26. The second insulating layer 22 is then deposited over the conductive material 32 and the first insulating layer 26.

[0033] The plurality of vias or openings are formed in either or both of the insulating layers 22 and 26 at preselected locations proximate to the pattern of conductive material or trace 32, 32' in order to communicate and expose the conductive trace 32 or 32'.

As seen in FIG. 2, one of the openings is provided on the first insulating layer 26, while a second opening is provided on the second insulating layer 22. Both openings, however, are situated to be in communication with the metalized trace 32 deposited on the first insulating layer and between the upper surface 27 of the first insulating layer 26 and the lower surface 25 of the second insulating layer 22. The multiple openings are then filled with a suitable conductive material that forms the conductive vias 35, 35' and 36, 36' which establish an electrical communication with the pattern of conductive material 32.

[0034] A metal cover 40 is then placed over one or more of the conductive vias 35, 35' and hermetically bonded to the appropriate insulating layer. As seen in FIG. 2, the metal cover 40 is disposed over interior conductive vias 35, 35' and hermetically bonded to the upper surface 23 of the second insulating layer 22. The metal cover 40 is preferably shaped such that it forms a hermetic cavity 42 immediately above the interior conductive vias 35, 35'. In addition, the metal cover 40 is situated such that it shrouds the electronic components 50, or other circuitry, of the implantable device. The interior conductive vias 35, 35' are further connected to the electronics 50, as required.

[0035] The arrangement shown in FIG. 2 provides that at least two interior conductive vias 35, 35' are exposed within the interior 46 of the hermetically sealed cavity 42 formed under the cover 40, while the exterior conductive vias 36, 36' are exposed outside of the hermetically sealed cavity 42 and on the opposite surface from the hermetically sealed cavity 42 as the lower surface 29 of the first insulating layer 22. An electrical path, or hermetic feedthrough 30 is thus formed through the respective conductive vias 35, 36, and conductive trace 32, as well as through the conductive vias 35', 36' and the conductive trace 32', so that electrical continuity is provided between the outside and inside of the hermetically sealed case 10 and on opposite surfaces 23,29 of the adjoining insulating layers 22,26.

[0036] Turning next to FIG. 3, yet another embodiment of a hermetically sealed case 10 for implantable electronic devices is shown. The embodiment shown in FIG. 3 is comprised of a plurality of layers of insulating material 22,26, and a frame 80 to which a lid 82 has having been hermetically sealed. The electrical components 50, or other circuits, which include components such as silicon chips 52 and/or energy storage devices 54, are connected to external leads 96, 96' by hermetic feedthroughs 30, 30' which permit the flow of electrical currents through the case 10 while maintaining hermeticity. Various metalized patterns of a suitable conductive material 32, 32' such as gold (Au), platinum (Pt), or tungsten (W), or alloys thereof, are deposited between the insulating layers 22, 26 to form the electrical circuits and connections necessary for the implanted device to operate.

[0037] Specifically, the frame 80 is disposed on the upper surface 23 of the uppermost insulating layer 22 and surrounds the electronics 50 which preferably include a silicon chip 52 and the energy storage device 54 such as a capacitor. The insulating layers 22, 26 are preferably made from a thin layers of aluminum oxide Al_2O_3 or zirconium oxide Zr_2O_3 or magnesium oxide Mg_2O_3 or glass. The frame 80 is fabricated from a body-safe metal, and is preferably a thin structure properly dimensioned to surround the electronics 50. The frame material is preferably selected from those metals or alloys that readily form an instant oxide when heated, or when exposed to air or oxygen, i.e., that readily oxidize when heated in and/or exposed to an oxygen-containing atmosphere. It is important that the frame material and the insulating material have thermal coefficients of expansion that are approximately equal. This minimizes the risk of cracking when the frame 80 and the uppermost insulating layer 22 are bonded together at high temperature and then cooled. The frame 80, for example, may be made from an alloy of Titanium-Niobium (i.e., Ti and Nb), which is available from commercial sources. Advantageously, both the preferred aluminum oxide insulating layer and the Titanium-Niobium alloy frame have thermal coefficients of expansion of between 6×10^{-6} and 10×10^{-6} /°C.

[0038] The frame 80 and the uppermost insulating layer 22 are secured together by preferably forming a hermetically sealed, solderless bond between the insulating layer 22 and the frame 80. The preferred method of forming the bond is a diffusion bonding technique. This bonding technique involves the combination of high temperature, and high pressure in an inert atmosphere to bring the surfaces of the frame 80 and the uppermost insulating layer 22 together such that the titanium atoms fill the voids at the interface or diffusion bonding site 81 to adhere the frame 80 with the insulating layer 22. A method and apparatus for brazeless ceramic to metal bonding used in implantable devices is more fully disclosed in co-pending United States Patent Application Serial No. 08/319,580, filed 10/07/94, entitled Brazeless Ceramic-to-Metal Bond, now U.S. Patent No. 5,513,793 (published after the priority date of the present application).

[0039] The lid 82 is also made from bio-compatible and corrosion resistant body-safe metals typically used for implantable devices such as titanium, stainless steel or cobalt-chromium alloys, although titanium is preferred. The lid 82 is disposed on the frame 80 and forming the cavity 42 and covering the electronics 50 with a minimum of clearance therein. The lid 82 is preferably laser welded to the frame 80. The laser weld sites 83 as well as the diffusion bonding sites 81 may then be further encapsulated or shrouded within an epoxy sealant 95 or other protective coatings or membranes (not shown).

[0040] It is noted that the above description of the materials that may be used for the embodiment of the invention shown in FIG. 3 also applies to the other embodiments of the invention, e.g., those of FIGS. 1, 2 and

4-5.

[0041] FIG. 4 and FIG. 5 illustrate yet another embodiment of the hermetically sealed case 10 having multiple hermetic feedthroughs 30 for use in implantable electronic devices. FIG. 4 is an exploded perspective view of such other embodiment, while FIG. 5 is a side, cross-sectional view of such embodiment. As seen best in FIG. 4, the embodiment includes three individual insulating layers 100, 110, and 120 with a plurality of metalized patterns 103, 113, 123, and 133 and conductive openings or vias 105, 115, and 125 disposed therein. The embodiment of FIGS. 4-5 further includes a frame 80, metal lid 82, and associated electronics 50, which may be the same as described in previous embodiments.

[0042] The individual substrate layers or insulating layers each have elongated upper and lower planar surfaces with specialized metalized pattern formed thereon. These individual substrate layers are aligned and successively layered so as to form an implantable device having both internal and external electrical connections.

[0043] FIG. 4, for example, shows a first or top insulating layer 100 having a plurality of metalized patterns 103 representing various electrical connections or circuitry. The top insulating layer 100 also has a plurality of holes or openings that have been filled with a suitable conductive material, e.g., a metal, to form a plurality of conductive vias 105. Each of the conductive vias 105 are formed at preselected locations proximate the metalized patterns 103 and in electrical contact therewith. The conductive vias 105 extend in a vertical direction from the upper surface 107 to the lower surface 109 and provide predetermined electrical connections from the electronic components 50 and metalized patterns 103 on the top insulating layer 100 to the adjacent intermediate layer 110.

[0044] The intermediate layer 110 also has a plurality of independent metalized patterns 113 deposited on an upper surface 117. As seen in FIGS. 4-5, the intermediate insulating layer 110 is aligned with the top insulating layer 100 such that the conductive vias 105 of the top insulating layer 100 are in electrical contact with the metalized patterns 113 on the intermediate insulating layer 110. Such alignment is generally represented by the target areas outlined on the intermediate insulating layer 110. The intermediate insulating layer 110 also has a plurality of conductive vias 115 which extend from the upper surface 117 to the lower surface 119 that represent electrical paths or conduits which are adapted to provide electrical connections to the adjacent insulating layer 120 immediately below the intermediate insulating layer 110.

[0045] A bottom insulating layer 120 is aligned with the intermediate insulating layer 110 such that the conductive vias 115 of the intermediate insulating layer 110 are in electrical contact with the metalized patterns 123 on the upper surface 127 of the bottom insulating layer 120. As before, such alignment is generally represented by the target areas outlined on the upper surface 127 of the bottom insulating layer 120. Much like the two prior insulating layers, the bottom insulating layer 120 also has a plurality of independent metalized patterns deposited on the upper surface 127 and a plurality of openings which have been filled with a suitable conductive material to form conductive vias 125. The conductive vias 125 represent electrical paths or conduits which are aligned to provide vertical electrical connections to whatever metalized patterns may be required on the lower surface (not visible in FIG. 4) of the bottom insulating layer 120.

[0046] As seen in the embodiment of FIGS. 4 and 5, such embodiment is comprised of a plurality of layers of insulating material 100, 110, 120, a frame 80 and a lid 82 having been hermetically sealed together. Although only three insulating layers and six hermetic paths are shown, it is readily apparent that any number of insulating layers and hermetic paths can be aligned, connected, and covered in the manner described above to provide the hermetic feedthroughs required in many implantable divides. As in the prior embodiments, the frame 80 is preferably diffusion bonded to the uppermost insulating layer 100 utilizing the brazeless bonding technique hereinbefore described, but it is to be understood that any suitable bonding technique may be used for this purpose. The lid 82 is preferably laser welded to the frame 80. The laser weld sites as well as the diffusion bonding sites may then be further encapsulated or shrouded within an epoxy sealant 95.

[0047] As indicated above, the preferred method of depositing the insulating layers is using ion enhanced evaporated sputtering of aluminum oxide, magnesium oxide or zirconium oxide so as to form a high quality insulation layer over the target substrate or other material. A hybrid ceramic may also be used as one or more of the insulating layers. The openings may then be formed, e.g., by masking portions of any underlying metalized patterns as the insulating layer is being deposited. The openings or holes are then filled with a suitable conductive metal such as platinum or gold or tungsten to form the conductive vias. The aforementioned metalized patterns or traces are deposited or etched on the insulating layers using conventional thin film deposition, or metalized etching techniques, as are common in the printed circuit board and integrated circuit fabrication arts.

[0048] In all of the above described embodiments of the present invention, the hermetically sealed cases and hermetic feedthroughs can be made extremely thin. In fact, the constituent parts of the described embodiments can be on the order of a mil or a few mils thick. For example, using currently known processing techniques, the frame and lid can be as thin as approximately 102 x 10^{-6} m (4 mils). The height of the cavity can be as small as about between 127 x 10^{-6} to 254 x 10^{-6} m (5 to 10 mils) depending on the connections of the electronics contained within the cavity. The insulating layers as indicated above, can be on the order of less than 25.4 x 10^{-6} m (1 mil) thick, it is thus feasible using presently

available processing techniques to construct an implantable device less than 635 x 10^{-6} m (25 mils) thick, yet still providing an hermetically sealed case and hermetic feedthroughs. As processing techniques improve, the such dimensions will be even smaller.

[0049] From the foregoing, it should be appreciated that the present invention thus provides an improved hermetically sealed case having hermetic feedthroughs.

Claims

1. An hermetically sealed electrical feedthrough (30,30') suitable for implantation of a medical device within living tissue of a patient comprising:

    a plurality of insulating layers (22, 26), each of the insulting layers being successively stacked with and hermetically bonded to adjacent layers, the plurality of layers having a plurality of corrosion resistant vias (35, 36) located in selected insulating layers and transversely passing therethrough;
    one or more conductive traces (32) placed on selected insulating layers, each conductive trace being in electrical contact with at least two of the vias, and each conductive trace being hermetically bonded to the insulating layer above it and below it;
    each of said vias having a conductive material therein that makes electrical contact with the conductive trace; and
    a biocompatible, corrosion resistant cover (40) diffusion bonded to one insulating layer to form an hermetically sealed cavity (42), wherein at least one conductive via (35) resides inside of the hermetically sealed cavity, and wherein at least one other conductive via (36) resides outside of the hermetically sealed cavity;
    whereby electrical contact may be made through the at least one other conductive via (36) that resides outside of the hermetically sealed cavity with the at least one conductive via (35) that resides inside of the hermetically sealed cavity through the conductive trace (32) that is in contact with said vias.

2. The hermetically sealed electrical feedthrough as set forth in claim 1 wherein the plurality of insulating layers comprises:

    a first insulating layer (26) having the conductive trace (32) deposited thereon, the first insulating layer having a via (36) therethrough that communicates with the conductive trace; and
    a second insulating layer (22) deposited over the conductive trace (32) and the first insulating layer (26), the second insulating layer having a via (35) therethrough that connects to the conductive trace.

3. The hermetically sealed electrical feedthrough as set forth in claim 2 wherein the cover (40) comprises a metal cover having a flange (44) around its periphery and a formed raised center, the flange being hermetically bonded to one of the insulating layers such that at least one conductive via (35) is accessible from inside of the hermetically sealed cavity formed under the raised center of the metal cover, and at least one other conductive via (36) is accessible from outside of the hermetically sealed cavity, the conductive vias, and conductive trace thereby comprising an electrical feedthrough (30) that provides a hermetic electrical connection between the conductive via (35) on the inside of the hermetically sealed cavity and the conductive via (36) on the outside of the hermetically sealed cavity.

4. The hermetically sealed electrical feedthrough as set forth in claim 1 wherein the plurality of insulating layers comprises:

    a first insulating layer (26) having the conductive trace (32) deposited thereon; and
    a second insulating layer (22) deposited over the conductive trace (32) and the first insulating layer (26), the second insulating layer having first and second openings therethrough that expose the conductive trace.

5. The hermetically sealed electrical feedthrough as set forth in claim 2 wherein the cover further comprises a metal cover having a flange (44) around its periphery and a formed raised center, the flange being hermetically bonded to the second insulating layer (22) such that at least one conductive via (35) resides inside of the hermetically sealed cavity (42) formed under the raised center of the metal cover, and at least one other conductive via (36) resides outside of the hermetically sealed cavity and spaced apart from the flange of the metal cover, the conductive vias and conductive trace thereby comprising an electrical feedthrough (30) that provides an electrical connection between the at least one conductive via (35) on the inside of the hermetically sealed cavity and the at least one conductive via (36) on the outside of the hermetically sealed cavity.

6. The hermetically sealed electrical feedthrough as set forth in claim 3 or 5 further comprising at least one electrical component (50) mounted within the hermetically sealed cavity (42) and electrically connected to the conductive via (35) inside the hermetically sealed cavity.

7. The hermetically sealed electrical feedthrough as

set forth in claim 1 wherein the plurality of insulating layers further comprise ceramic materials selected from the group consisting of aluminum oxides, zirconium oxides, magnesium oxides, and glass.

8. The hermetically sealed electrical feedthrough as set forth in claim 1 wherein the cover further comprises:

a metal frame (80) hermetically bonded to the insulating layers; and
a lid (82) hermetically bonded to the frame, the lid and metal frame thereby defining an hermetically sealed cavity (42) wherein at least one conductive via (35) resides, with at least one other conductive via (36) residing outside of the hermetically sealed cavity; and wherein the thermal coefficients of expansion of the frame (80) and the insulating layers (22, 26) are approximately equal.

9. The hermetically sealed electrical feedthrough as set forth in claim 8 wherein the metal frame (80) further comprises an Titanium-Niobium alloy and the insulating layers are formed from a ceramic material selected from the group consisting of aluminum oxides, zirconium oxides, magnesium oxides and glass.

10. The hermetically sealed electrical feedthrough as set forth in claim 9 wherein the metal frame (80) is hermetically bonded to the insulating layers using a brazeless ceramic to metal diffusion bonding technique.

11. The hermetically sealed electrical feedthrough as set forth in claim 8 wherein the lid (82) is formed from a body-safe metal selected from the group consisting of titanium, stainless steel and cobalt-chromium alloys.

12. The hermetically sealed electrical feedthrough as set forth in claim 8 wherein any bonded portions of the lid, frame and insulating layers are further encapsulated or shrouded within an epoxy sealant.

13. A method of forming an hermetically sealed electrical feedthrough (30) suitable for implantation of a medical device within living tissue of a patient, comprising the steps of:

preparing at least one insulating layer (22); forming a plurality of openings in selected locations of the at least one insulating layer; depositing at least one conductive trace (32) on the at least one insulating layer (22), each conductive trace being deposited so as to be in communication with one or more of the openings on the selected insulating layer;
inserting a conductive material into each of the openings, thereby forming corrosion resistant conductive vias (35, 36), the conductive vias being adapted to establish an electrical contact with the aligned conductive trace; and diffusion bonding a biocompatible, corrosion resistant cover (40) to at least one insulating layer (22) thereby forming a hermetically sealed cavity (42), with at least one conductive via (35) residing inside the hermetically sealed cavity formed under the cover, and
with at least one other conductive via (36) residing outside of the hermetically sealed cavity;

whereby an electrical feedthrough (30) is provided between the via (36) outside of the hermetically sealed cavity and the via (35) inside of the hermetically sealed cavity.

14. The method of forming an hermetically sealed electrical feedthrough as set forth in claim 13 further comprising mounting electrical components (52, 54) within the hermetically sealed cavity (42) and electrically connecting the electronic components to the conductive vias inside the hermetically sealed cavity.

Patentansprüche

1. Hermetisch abgedichtete elektrische Durchführung (30, 30'), die für eine Implantation einer medizinischen Vorrichtung in lebendes Gewebe eines Patienten geeignet ist, umfassend:

eine Vielzahl von Isolierschichten (22, 26), wobei jede der Isolierschichten mit angrenzenden Schichten aufeinanderfolgend gestapelt und mit diesen hermetisch verbunden ist, die Vielzahl von Schichten eine Vielzahl von korrosionsbeständigen Durchgangsverbindungen (35, 36) aufweist, welche sich in ausgewählten Isolierschichten befinden und durch diese quer hindurchgehen;

einen oder mehrere leitfähige Spurlinien (32), die auf ausgewählten Isolierschichten angeordnet sind, wobei jede leitfähige Spurlinie in elektrischem Kontakt mit mindestens zwei der Durchgangsverbindungen steht und jede leitfähige Spurlinie mit der Isolierschicht darüber und darunter hermetisch verbunden ist;

wobei jede der Durchgangsverbindungen ein leitfähiges Material aufweist, das mit der leitfähigen Spurlinie einen elektrischen Kontakt bildet; und einem biologisch verträglichen, korrosionsbestän-

digen Belag (40), der mit einer Isolierschicht diffussionsverbunden ist und eine hermetisch abgedichtete Kavität (42) bildet, wobei sich mindestens eine leitfähige Durchgangsverbindung (35) innerhalb der hermetisch abgedichteten Kavität befindet, und wobei sich mindestens eine weitere leitfähige Durchgangsverbindung (36) außerhalb der hermetisch abgedichteten Kavität befindet;
wobei ein elektrischer Kontakt hergestellt werden kann durch die mindestens eine weitere leitfähige Durchgangsverbindung (36), die sich außerhalb der hermetisch abgedichteten Kavität befindet, mit der mindestens einen leitfähigen Durchgangsverbindung (35), die sich innerhalb der hermetisch abgedichteten Kavität befindet und durch die leitfähige Spurlinie (32) verläuft, die mit den Durchgangsverbindungen in Kontakt steht.

2. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 1, wobei die Vielzahl von Isolierschichten folgendes umfasst:

   eine erste Isolierschicht (26) mit der auf dieser abgeschiedenen leitfähigen Spurlinie (32), wobei die erste Isolierschicht durch diese eine Durchgangsverbindung (36) aufweist, die mit der leitfähigen Spurlinie in Verbindung steht; und

   eine zweite Isolierschicht (22), welche über der leitfähigen Spurlinie (32) und der ersten Isolierschicht (26) abgeschieden ist, wobei die zweite Isolierschicht eine Durchgangsverbindung (35) durch diese aufweist, die mit der leitfähigen Spurlinie eine Verbindung bildet.

3. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 2, wobei der Belag (40) ein Metallbelag mit einem Flansch (44) um ihren Rand und ein gebildetes angehobenes Zentrum aufweist, wobei der Flansch mit einer der Isolierschichten hermetisch so verbunden ist, dass mindestens eine leitfähige Durchgangsverbindung (35) von innerhalb der hermetisch abgedichteten Kavität, welche unter dem angehobenen Zentrum des Metallbelags geformt ist, zugänglich ist, und mindestens eine weitere leitfähige Durchgangsverbindung (36) von außerhalb der hermetisch abgedichteten Kavität zugänglich ist, wobei die leitfähigen Durchgangsverbindungen und die leitfähige Spurlinie dadurch eine hermetische elektrische Durchführung (30) umfassen, die eine hermetische elektrische Verbindung zwischen der leitfähigen Durchgangsverbindung (35) an der Innenseite der hermetisch abgedichteten Kavität und der leitfähigen Durchgangsverbindung (36) an der Außenseite der hermetisch abgedichteten Kavität bilden.

4. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 1, wobei die Vielzahl der Isolierschichten umfasst:

   eine erste Isolierschicht (26) mit der auf dieser aufgebrachten leitfähigen Spurlinie (32); und

   eine zweite Isolierschicht (22), aufgebracht über der leitfähigen Spurlinie (32) und der ersten Isolierschicht (26),

   wobei die zweite Isolierschicht erste und zweite Öffnungen durch diese aufweist, durch die die leitfähige Spurlinie freilegt wird.

5. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 2, wobei der Belag ferner einen Metallbelag mit einem Flansch (44) um seinen Rand und ein gebildetes angehobenes Zentrum aufweist, wobei der Flansch mit der zweiten Isolierschicht (22) hermetisch so verbunden ist, dass sich mindestens eine leitfähige Durchgangsverbindung (35) innerhalb der hermetisch abgedichteten Kavität (42) befindet, welche unter dem angehobenen Zentrum des Metallbelags geformt ist, und sich mindestens eine weitere leitfähige Durchgangsverbindung (36) außerhalb der hermetisch abgedichteten Kavität befindet und in einem Abstand von dem Flansch des Metallbelags angeordnet ist, die leitfähigen Durchgangsverbindungen und eine leitfähige Spurlinie dadurch eine elektrische Durchführung (30) umfassen, die zwischen der mindestens einen leitfähigen Durchgangsverbindung (35) an der Innenseite der hermetisch abgedichteten Kavität und der mindestens einen leitfähigen Durchgangsverbindung (36) an der Außenseite der hermetisch abgedichteten Kavität eine elektrische Verbindung bildet.

6. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 3 oder 5, welche ferner mindestens eine elektrische Komponente (50) umfasst, die in der hermetisch abgedichteten Kavität (42) befestigt und mit der leitfähigen Durchgangsverbindung (35) innerhalb der hermetisch abgedichteten Kavität verbunden ist.

7. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 1, wobei die Vielzahl der Isolierschichten ferner Keramikmaterialien umfassen, welche aus der Gruppe ausgewählt sind, die aus Aluminiumoxiden, Zirkonoxiden, Magnesiumoxiden und Glas besteht.

8. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 1, wobei der Belag ferner umfasst:

   einen Metallrahmen (80), welcher mit den Iso-

lierschichten hermetisch verbunden ist; und

einen Deckel (82), welcher mit dem Rahmen hermetisch verbunden ist,

wobei der Deckel und der Metallrahmen auf diese Weise eine hermetisch abgedichtete Kavität (42) bilden, in welchem sich mindestens eine leitfähige Durchgangsverbindung (35) befindet, mit mindestens einer weiteren leitfähigen Durchgangsverbindung (36), welche sich außerhalb der hermetisch abgedichteten Kavität befindet; und wobei die Wärmekoeffizienten der Ausdehnung des Rahmens (80) und der Isolierschichten (22, 26) ungefähr gleich sind.

9. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 8, wobei der Metallrahmen (80) ferner eine Titan-Niobium-Legierung umfasst und die Isolierschichten aus einem Keramikmaterial gebildet sind, ausgewählt aus der Gruppe bestehend aus Aluminiumoxiden, Zirkonoxiden, Magnesiumoxiden und Glas.

10. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 9, bei welcher der Metallrahmen (80) unter Verwendung einer lötfreien Keramik-auf-Metall-Diffusionsverbindungstechnik mit den Isolierschichten hermetisch verbunden ist.

11. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 8, bei welcher der Deckel (82) aus einem körperverträglichen Metall geformt ist, ausgewählt aus der Gruppe bestehend aus Titan, rostfreiem Stahl und Kobalt-Chrom-Legierungen.

12. Hermetisch abgedichtete elektrische Durchführung nach Anspruch 8, bei welcher beliebige verbundene Teile des Deckels, des Rahmens und der Isolierschichten weiter innerhalb eines Epoxidharzabdichtungsmittel eingekapselt oder damit umhüllt sind.

13. Verfahren zur Bildung einer hermetisch abgedichteten elektrischen Durchführung (30), welche zur Implantation einer medizinischen Vorrichtung in ein lebendes Gewebe eines Patienten geeignet ist, umfassend die Schritte:

Herstellung von mindestens einer Isolierschicht (22); Bildung einer Vielzahl von Öffnungen an ausgewählten Bereichen der mindestens einen Isolierschicht; Abscheiden von mindestens einer leitfähigen Spurlinie (32) auf der mindestens einen Isolierschicht (22), wobei jede leitfähige Spurlinie so abgeschieden wird, dass sie mit einer oder mehreren der Öffnungen auf der ausgewählten Isolierschicht in Verbindung steht;

Einfügen eines leitfähigen Materials in jede der Öffnungen unter Bildung von korrosionsbeständigen, leitfähigen Durchgangsverbindungen (35, 36), wobei die leitfähigen Durchgangsverbindungen so angepasst sind, dass sie mit der zugeordneten, leitfähigen Spurlinie einen elektrischen Kontakt herstellen; Herstellung einer diffusionsverbindung zwischen einem biologisch verträglichen, korrosionsbeständigen Belag (40) und mindestens einer Isolierschicht (22), wobei eine hermetisch abgedichtete Kavität (42) gebildet wird, wobei sich mindestens eine leitfähige Durchgangsverbindung (35), welche sich innerhalb der unter dem Belag gebildeten, hermetisch abgedichteten Kavität befindet, und wobei sich mindestens eine weitere leitfähige Durchgangsverbindung (36),. außerhalb der hermetisch abgedichteten Kavität befindet;

wodurch zwischen der Durchgangsverbindung (36) außerhalb der hermetisch abgedichteten Kavität und der Durchgangsverbindung (35) innerhalb der hermetisch abgedichteten Kavität eine elektrische Durchführung (30) vorgesehen wird.

14. Verfahren zum Formen einer hermetisch abgedichteten elektrischen Durchführung nach Anspruch 13, ferner umfassend:

Befestigen elektrischer Komponenten (52, 54) innerhalb der hermetisch abgedichteten Kavität (42) und elektrisches Verbinden der elektronischen Komponenten mit den leitfähigen Durchgangsverbindungen innerhalb der hermetisch abgedichteten Kavität.

Revendications

1. Traversée électrique scellée hermétiquement (30, 30') convenant à une implantation d'un dispositif médical à l'intérieur d'un tissu vivant d'un patient comprenant :

une pluralité de couches isolantes (22, 26), chacune des couches isolantes étant successivement empilée avec des couches adjacentes et hermétiquement liées à celles-ci, la pluralité de couches comportant une pluralité de trous traversants résistant à la corrosion (35, 36) situés dans des couches isolantes sélectionnées et passant transversalement au travers de celles-ci,

une ou plusieurs pistes conductrices (32) pla-

cées sur des couches isolantes sélectionnées, chaque piste conductrice étant en contact électrique avec au moins deux des trous traversants, et chaque piste conductrice étant liée hermétiquement à la couche isolante au-dessus et en dessous de celle-ci,

chacun desdits trous traversants comportant un matériau conducteur dans celui-ci qui établit un contact électrique avec la piste conductrice, et

une protection biocompatible résistant à la corrosion (40) liée par diffusion à une couche isolante afin de former une cavité hermétiquement scellée (42), dans laquelle au moins un trou traversant conducteur (35) réside à l'intérieur de la cavité hermétiquement scellée, et dans laquelle au moins un autre trou traversant conducteur (36) réside- à l'extérieur de la cavité hermétiquement scellée,

grâce à quoi un contact électrique peut être établi par l'intermédiaire du au moins un autre trou traversant conducteur (36) qui réside à l'extérieur de la cavité hermétiquement scellée avec le au moins un trou traversant conducteur (35) qui réside à l'intérieur de la cavité hermétiquement scellée par l'intermédiaire de la piste conductrice (32) qui est en contact avec lesdits trous traversants.

2. Traversée électrique hermétiquement scellée selon la revendication 1, dans laquelle la pluralité de couches isolantes comprend :

   une première couche isolante (26) comportant la piste conductrice (32) déposée sur celle-ci, la première couche isolante comportant un trou traversant (36) au travers de celle-ci qui communique avec la piste conductrice, et

   une seconde couche isolante (22) déposée sur la piste conductrice (32) et la première couche isolante (26), la seconde couche isolante comportant un trou traversant (35) au travers de celle-ci qui est connecté à la piste conductrice.

3. Traversée électrique hermétiquement scellée selon la revendication 2, dans laquelle la protection (40) comprend une protection métallique comportant un rebord (44) autour de sa périphérie et un centre bombé formé, le rebord étant lié hermétiquement à l'une des couches isolantes de sorte qu'au moins un trou traversant conducteur (35) soit accessible de l'intérieur de la cavité hermétiquement scellée formée sous le centre bombé de la protection métallique, et au moins un autre trou traversant conducteur (36) est accessible de l'extérieur de la cavité hermétiquement scellée, les trous traversants conducteurs, ainsi que la piste conductrice constituant ainsi une traversée électrique (30) qui permet une connexion électrique hermétique entre le trou traversant conducteur (35) sur l'intérieur de la cavité hermétiquement scellée et le trou traversant conducteur (36) sur l'extérieur de la cavité hermétiquement scellée.

4. Traversée électrique hermétiquement scellée selon la revendication 1, dans laquelle la pluralité de couches isolantes comprend :

   une première couche isolante (26) comportant la piste conductrice (32) déposée sur celle-ci, et

   une seconde couche isolante (22) déposée sur la piste conductrice (32) et la première couche isolante (26), la seconde couche isolante comportant des première et seconde ouvertures au travers de celle-ci qui exposent la piste conductrice.

5. Traversée électrique hermétiquement scellée selon la revendication 2, dans laquelle la protection comprend en outre une protection métallique comportant un rebord (44) autour de sa périphérie et un centre bombé formé, le rebord étant hermétiquement lié à la seconde couche isolante (22) de sorte qu'au moins un trou traversant conducteur (35) réside à l'intérieur de la cavité hermétiquement scellée (42) formée sous le centre bombé de la protection métallique, et au moins un autre trou traversant conducteur (36) réside à l'extérieur de la cavité hermétiquement scellée et il est espacé du rebord de la protection métallique, les trous traversants conducteurs et la piste conductrice constituant ainsi une traversée électrique (30) qui permet une connexion électrique entre le au moins un trou traversant conducteur (35) à l'intérieur de la cavité hermétiquement scellée et le au moins un trou traversant conducteur (36) à l'extérieur de la cavité hermétiquement scellée.

6. Traversée électrique hermétiquement scellée selon la revendication 3 ou 5, comprenant en outre au moins un composant électrique (50) monté à l'intérieur de la cavité hermétiquement scellée (42) et relié électriquement au trou traversant conducteur (35) à l'intérieur de la cavité hermétiquement scellée.

7. Traversée électrique hermétiquement scellée selon la revendication 1, dans laquelle la pluralité de couches isolantes comprend en outre des matériaux de céramique sélectionnés à partir du groupe consti-

tué des oxydes d'aluminium, des oxydes de zirconium, des oxydes de magnésium, et du verre.

8. Traversée électrique hermétiquement scellée selon la revendication 1, dans laquelle la protection comprend en outre :

   un cadre métallique (80) lié hermétiquement aux couches isolantes, et

   un couvercle (82) lié hermétiquement au cadre, le couvercle et le cadre métallique définissant ainsi une cavité hermétiquement scellée (42) dans laquelle au moins un trou traversant conducteur (35) réside, au moins un autre trou traversant conducteur (36) résidant à l'extérieur de la cavité hermétiquement scellée, et dans laquelle

   les coefficients de dilation thermique du cadre (80) et des couches isolantes (22, 26) sont approximativement égaux.

9. Traversée électrique hermétiquement scellée selon la revendication 8, dans laquelle le cadre métallique (80) comprend en outre un alliage de titane-niobium et les couches isolantes sont formées à partir d'un matériau de céramique sélectionné parmi le groupe constitué des oxydes d'aluminium, des oxydes de zirconium, des oxydes de magnésium et du verre.

10. Traversée électrique hermétiquement scellée selon la revendication 9, dans laquelle le cadre métallique (80) est lié hermétiquement aux couches isolantes en utilisant une technologie de liaison par diffusion de céramique sur métal sans brasure

11. Traversée électrique hermétiquement scellée selon la revendication 8, dans laquelle le couvercle (82) est formé à partir d'un métal sain pour le corps sélectionné à partir du groupe constitué de titane, de l'acier inoxydable et des alliages cobalt-chrome.

12. Traversée électrique hermétiquement scellée selon la revendication 8, dans laquelle des parties liées quelconques du couvercle, du cadre et des couches isolantes sont en outre encapsulées ou enveloppées dans un agent d'étanchéité d'époxy.

13. Procédé de formation d'une traversée électrique hermétiquement scellée (30) convenant à l'implantation d'un dispositif médical à l'intérieur d'un tissu vivant d'un patient, comprenant les étapes consistant à :

   préparer au moins une couche isolante (22), former une pluralité d'ouvertures à des emplacements sélectionnés de la au moins une couche isolante, déposer au moins une piste conductrice (32) sur la au moins une couche isolante (22), chaque piste conductrice étant déposée de façon à être en communication avec une ou plusieurs des ouvertures sur la couche isolante sélectionnée,

   insérer un matériau conducteur dans chacune des ouvertures, en formant ainsi des trous traversants conducteurs (35, 36) résistant à la corrosion, les trous traversants conducteurs étant conçus pour établir un contact électrique avec la piste conductrice alignée, et lier par diffusion une protection résistant à la corrosion biocompatible (40) à au moins une couche isolante (22) en formant ainsi une cavité hermétiquement scellée (42), au moins un trou traversant conducteur (35) résidant à l'intérieur de la cavité hermétiquement scellée formée sous la protection, et au moins un autre trou traversant conducteur (36) résidant à l'extérieur de la cavité hermétiquement scellée ;

   grâce à quoi une traversée électrique (30) est obtenue entre le trou traversant (36) à l'extérieur de la cavité hermétiquement scellée et le trou traversant (35) à l'intérieur de la cavité hermétiquement scellée.

14. Procédé de formation d'une traversée électrique hermétiquement scellée selon la revendication 13, comprenant en outre le montage de composants électroniques (52, 54) à l'intérieur de la cavité hermétiquement scellée (42) et la connexion électrique des composants électroniques sur les trous traversants conducteurs à l'intérieur de la cavité hermétiquement scellée.

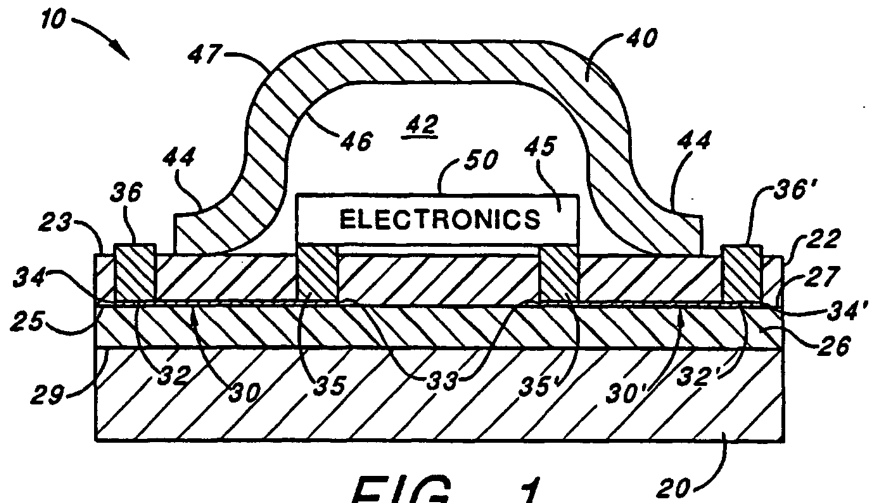

FIG. 1

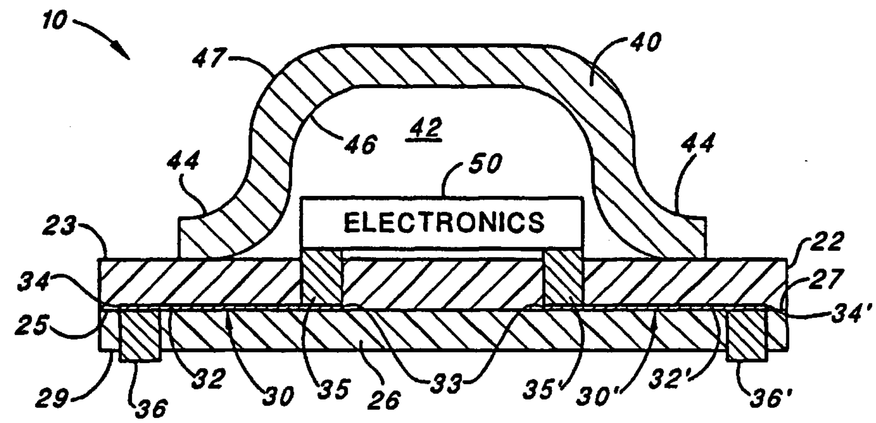

FIG. 2

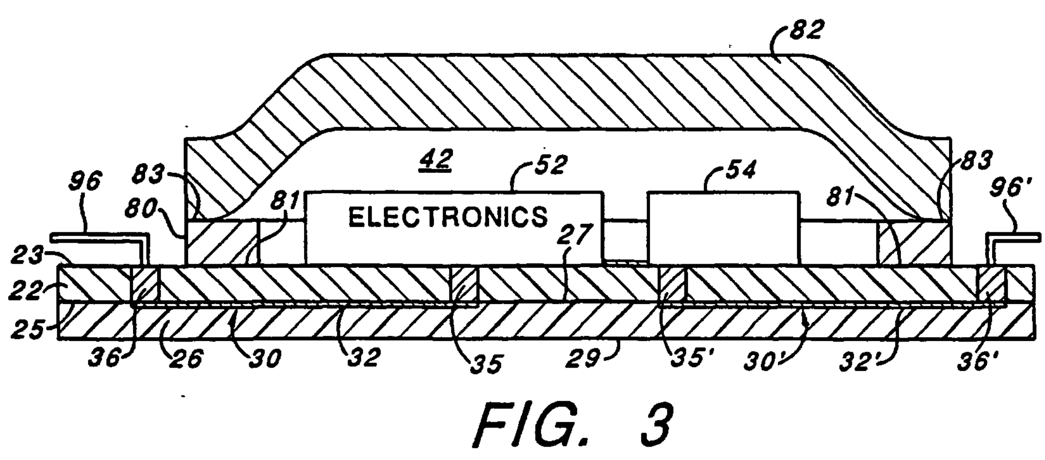

FIG. 3

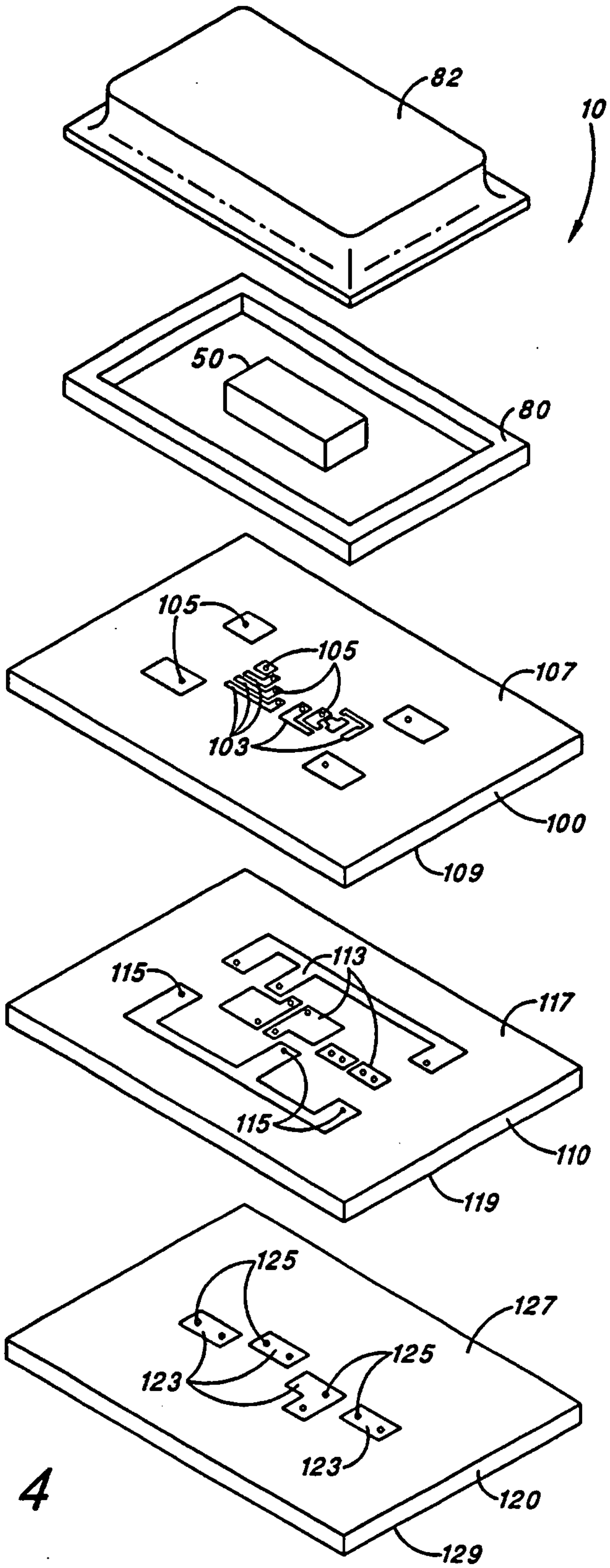
82
10
50
80
105
105
107
103
100
109
115
113
117
115
110
119
125
127
125
123
123
120
129

FIG. 4

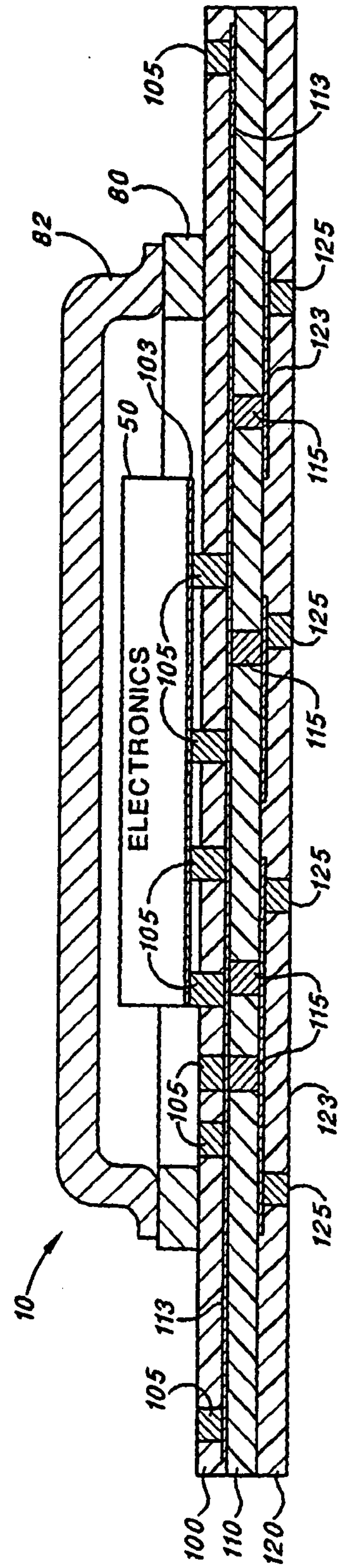
105
113
82
80
125
123
103
50
115
ELECTRONICS
105
105
125
115
125
105
105
115
105
123
125
10
113
105
100
110
120

FIG. 5